

What Variations in Trace Element Enrichments of Sandstone-Hosted Uranium Deposits Tell Us about Source Rocks, Redox Conditions and Groundwater Compositions Necessary for Ore Formation

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The enrichment of trace elements in sandstone-hosted uranium deposits, including chromium (Cr), selenium (Se), vanadium (V), arsenic (As), and molybdenum (Mo), continue to provide insights into origin of the deposits. These elements form soluble oxyanions in oxic environments and they precipitate sequentially with decreasing Eh. Understanding the plausible sources of these elements, conditions of transport, and controls on their mobility/fixation have been furthered by recent investigations of rock weathering and modern groundwater compositions. Proposed sources for U and associated trace elements include weathering/dissolution of volcanic ash, granites, shale, and detrital heavy minerals within the host sandstone. The element assemblage (Cr, Se, V, and Mo) associated with Salt Wash-hosted V deposits of the Morrison Formation indicates a mixed source, whereas the common association of U with Se, Mo, and As is attributed to a silicic igneous source. Studies of weathering of metalliferous black shales in semi-arid and temperate climates showed that environments hosting circum-neutral pH water favor desorption of As, Mo, and V onto particle surfaces, whereas environments with alkaline pH (>8.5) promotes desorption and mobility of these elements. Alkaline pH can result from silicate hydrolysis, progressive evaporation of water in which $\text{Ca}^{2++} \text{Mg}^{2+} < \text{HCO}_3^-$, and cation exchange reactions in the subsurface. The latter two scenarios are evident in modern alkaline, metalliferous groundwater in Tertiary basin fill in southwestern Nevada, and a Permian quartz arenite aquifer in Oklahoma, respectively. Primary ore formation was favored by ancient alkaline groundwater, which is substantially different from modern groundwater in many mineralized-sandstones.